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THE INVESTIGATION OF MECHANICAL AND METALLURGICAL PROPERTIES ON Al7075-TiC-SiC REINFORCED HYBRID COMPOSITES BY STIR CASTING

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ABSTRACT

MMCs restrain thermal conductivity and ductility of metals and high stiffness, high hardness, and low thermal conductivity in the case of ceramics. Space, aerospace, automotive and electrical industries utilizes composites due to their excellent physical and mechanical properties. But MMCs have insufficient process stability, reliability and efficiency. To rectify this problem, the HMMCs were developed. The reinforcement phase improves the mechanical properties of composite. In this research, the mechanical characteristics of Al HMMC have been investigated. Al7075 alloy was considered as matrix phase and Silicon Carbide (SiC) and Titanium Carbide (TiC) as reinforcements for fabrication of HMMC by Stir Casting Technique. The tests were carried out as per ASTM standards to find mechanical properties such as yield strength, Brinell hardness ultimate Tensile strength, and Impact strength of HMMC specimen and also metallurgical properties were studied.

KEYWORDS: Composites, Hybrid Metal, MMC & HMMC

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Original Article

INTRODUCTION

Since aluminium is less dense than steel, better corrosion resistant, high mechanical and recycling characteristics, Al alloys are used abundantly in many sectors such as aerospace and automobile. Al MMCs reinforced with ceramic particles gain popularity as high performance composites because of their better strength, high young's modulus and improved wear resistance, their superior strength-to-weight ratio, strength- to-cost ratio over traditional base alloys [1, 2]. Al based MMC is engineered by combining metal Matrix and hard particle ceramic as Reinforcement to get excellent properties. MMCs are utilized for space shuttle, bicycles, commercial airliners, automobiles, electronic substrates, golf clubs, and many other applications. Similar to all other composites, Al-matrix composites are a family of materials whose strength, stiffness, thermal, density and electrical properties can be made better. The matrix phase, reinforcement material, volume percentage and reinforcement shape, location and fabrication techniques can be differed to achieve necessary characteristics. The aim of designing and fabricating MMC materials is to obtain the desirable attributes from both metals and ceramics. The addition of high strength, high young's modulus refractory reinforcement to a ductile metal matrix produces a material with mechanical properties intermediate between the matrix alloy phase and the ceramic reinforcement particles.

Metals are ductile and possess good strength and high temperature resistance nature, but are subjected to low stiffness, whereas non metals such as ceramics have high stiffness and strength, even though brittle in nature

[3]. Carefully controlling the amount of reinforcements and uniform distribution of ingredients of composite and manufacturing conditions, the characteristics can be further improved. The relation between tensile strength and scratch resistance in particle reinforced MMCs prepared by techniques of powder metallurgy [4] is better. By studying SiC reinforced aluminium alloys microstructure produced, it was shown that stability of SiC in the variety of manufacturing techniques available for melt was dependent on the matrix alloy involved [5]. Stir casting is generally practiced commercially among discontinuous metal matrix composites manufacturing processes, accepted as a particularly promising route, currently. Its simplicity, reliability, flexibility and applicability to large quantity production can be considered as advantages. It is attractive because, it allows a traditional metal processing method to be used, in principle and hence reduces the total product cost. This method is the most economical of all the available methods for MMC production [6] and very large sized components can be fabricated. The composites preparation cost using this method is about one-third to half that of competitive methods, and for production in high volumes, the cost will fall to one-tenth [7]. The Al 6061-TiB2 in-situ MMCs manufactured using stir casting method using Al 6061 as the matrix material phase and Al-10% Ti and Al-3% B as reinforcement phases. The prepared in-situ MMCs exhibited considerable betterment in the mechanical characteristics as compared to the base metal [8]. The mechanical characteristics of Al metal matrix are improved by adding SiC reinforcement [9]. By varying mass fractions of 5%, 10%, 15%, and 20%, the micro structural behavior of aluminum with SiC (grit size 60) was observed and found there is a uniform distribution of silicon carbide in Al metal matrix [10]. Al6061 reinforced with TiB2 particles was produced by stir casting method. Experimentation was carried out by varying weight fraction of TiB2 (0%, 4%, 8% and 12%), by keeping remaining parameters as constant. This study revealed that addition of TiB2 reinforcement improves the wear resistance nature of aluminium composites. The results showed that increase in mechanical characteristics, such as wear resistance and hardness were caused by the addition of TiB2 present in the samples [11]. The hardness of MMC increases with increased reinforcement content and the wear rate of the Al6061-SiC composite decreased with higer SiC content [12]. Reinforcements SiC and TiB2 with aluminum matrix forms a HMMC. The TiB2 addition to MMCs observations shows exponential enhanced stiffness, hardness and wear resistance [13].

The objective of the present work is to estimate the mechanical characteristics of Al7075 alloy, randomly reinforced with two varieties of reinforcements SiC and TiC. The stir technique is selected for fabricating of HMMCs. The mechanical behavior is improved by the reinforcement TiC and SiC combination and impact strength was reduced.

EXPERIMENTAL DETAILS

The base matrix metal for the present studies is Al 7075 (Indiamart) and the reinforcement particles are SiC and TiC (Bangalore). The chemical composition by weight % of matrix phase and properties of matrix alloy and reinforcing materials are tabulated in Table 1 and Table 2.

Table 1: Chemical Composition of Al7075 by Weight Percentage

Chemical Composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al7075	0.4%	0.5%	1.6%	0.3%	2.5%	0.15%	5.5%	2.2%	Remaining%

Table 2: Properties of Matrix and Reinforcement Material

Properties	Al 7075	SiC	TiC
Young's Modulus (Gpa)	70-80	410	493
Density (g/cc)	2.81	3.1	4.9
Poisson's Ratio (μ)	0.33	0.14	0.187
Hardness (HB500)	60	2800	3400
Tensile Strength (T) (Mpa) / Compressive Strength (C) (Mpa)	220(T)	3900(C)	118(T)

Hybrid composite samples were manufactured by stir casting method. The amount of the matrix material phase and the reinforcements phases were determined by calculating the volume %. 4 and 6 vol. % of SiC and TiC reinforcements were mixed in hybrid composite material preparation. The Al alloy was melt in the furnace and the stirred with the help of speed regulator and fire resistant stirring motor arrangement. The set up is shown in Figure 1. The reinforcements SiC and TiC particles were preheated and added into Aluminium melt. The Al alloy was heated above the liquidus temperature to completely melt. It was lightly cooled below that liquidus temperature to maintain the semi-solid state slurry. The molten metal is combined with preheated reinforcements and mixed well with stirrer. Then the entire composite slurry was reheated to a liquid state and at an average mixing speed of 150 to 200 rpm mechanical mixing was carried out for about 10 to 15 min. The final temperature was maintained to be around 820°C ±30 °C.

Finally, the molten composite was shifted to a mould; the fabricated HMMCs are shown in Figure 2. The HMMCs having different wt. % of SiC and TiC were prepared by the same process. In this paper, Sample1 is pure Al7075, sample2 contains 95 % Al7075 + 5 % SiC, sample3 with 95 % Al7075 + 5 % TiC, sample4 has 90 % Al7075 + 4% SiC+6% TiC and sample5 contains 90% Al7075 +6 % SiC + 4 % TiC

Figure 1: Stir Casting Equipment

Figure 2: Sample

Evaluation of Mechanical Properties of HMMCS

The tensile tests were performed to check the mechanical properties of matrix alloy and HMMC samples. The tensile specimens were prepared according ASTM E08 standard [14] from the sample HMMCs. The specimen dimensions are given in Figure 3.

The UTS was calculated by using a computerized universal testing machine (UTE-40). Three specimens prepared from each HMMC and base alloy, were experimented and the average tensile strength value was estimated.

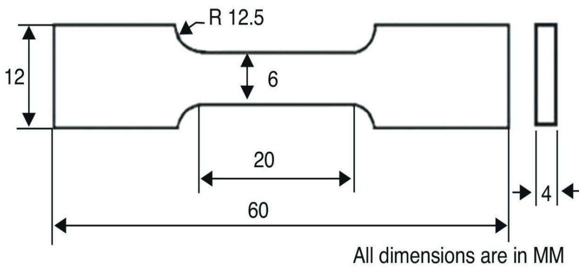

Figure 3: Dimensions of Tensile Specimen of AA7075-SiC and TiC

The energy grasped by the specimen under sudden dynamic loads was tested using impact test. As per IS: 1757 standards, the specimen was prepared. In this work, the Charpy and Izod impact test was used to find the impact strength of the samples. To determine the composites hardness, the Brinell hardness test was conducted and BHN was found. The micro hardness of polished samples was measured at different locations using the Brinell hardness at a load of 1000 grams for 10 sec.

Evaluation of Metallurgical Properties of HMMCs

The microstructure of HMMCs produced was studied by optical microscope [15, 16]. A section cut from the castings, was first belt ground following intermediate polishing operation on different grade of emery papers. After that specimens were fine polished on velvet cloth to remove nicks and burrs. Samples were etched and microstructure was observed under optical microscope at various magnifications.

RESULTS AND DISCUSSIONS

Characterization of AA 7075+SiC+TiC HMMC

Al reinforced with SiC and TiC particulate reinforced HMMCs were produced by stir casting technique. Flux addition has improved the wettability of SiC particles in Al matrix [17]. The flux reacts with molten surface of Sic particle and forms Ti layers around SiC particle surface. This exothermic reaction evolves heat and enhances the vicinity of SiC particle-melt interface and incorporates particles uniformly into the melt.

Mechanical Properties

The evaluated mechanical characteristics of Al HMMCs are listed in Table 3.

Table 3: Mechanical Properties of AA7075 HMMC Reinforced with SiC and TiC

Test Samples	UTS (N/mm^{2})	Hardness (BHN)	Yield Stress (N/mm^2)	Impact Strength (Joules)
AA7075	320	95	310	2.31
AA7075+5%SiC	330	149	319	2.62
AA7075+5%TiC	345	195	328	3.34
AA7075+4%SiC+6%TiC	348	196	325	4.00
AA7075+6%SiC+4%TiC	360	222.3	345	5.00

Hardness Test

The mechanical characters of matrix phase alloy A7075 were increased by SiC and TiC addition. From table 3, it is clear that HMMCs hardness is improved as the particulates phase amount increases. Reinforcement particles incorporation in the matrix improves the reinforcement surface area. Such hard surface of particles shows higher resistance to plastic deformation and increases hardness of composites. It is reported that the presence of hard ceramic phase in the

soft ductile matrix significantly increases the hardness value due to reduction of ductile metal content which reduces the ductility of composites.

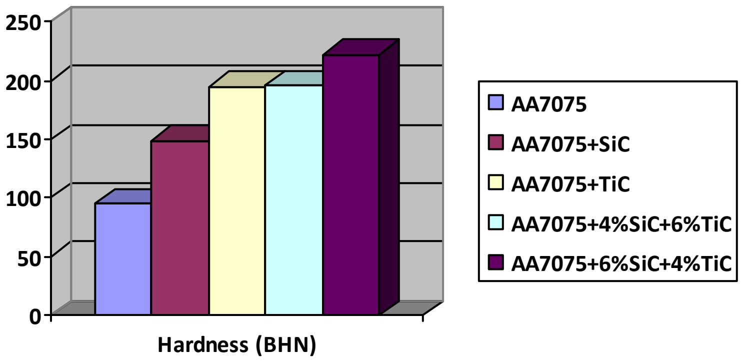

Figure 4: Graphical Representation of Hardness Test

Tensile Test

In table 3 the percentage of elongation, ultimate tensile strength and yield strength and of HMMCs are tabulated.

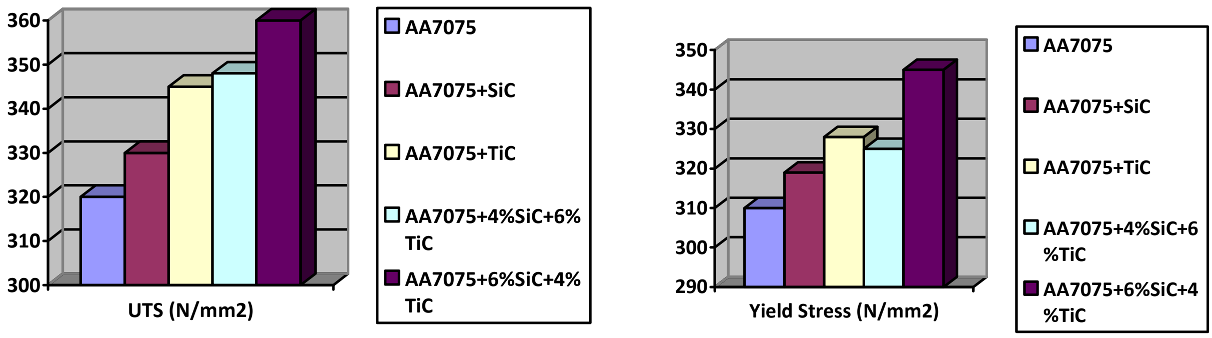

Figure 5: Graphical Representation of Tensile Stress and Yield Stress

It can be identified that SiC and TiC particulates play an effective role in increasing the HMMC tensile strength from 320 MPa to 360 MPa, due to the strengthening mechanism of the reinforcement. SiC and TiC particles reinforcement in the matrix offers more resistance to tensile stresses and adds greater strength to matrix alloy. The temperature difference between the matrix and the reinforcement phases causes higher dislocation density in the matrix and load bearing capacity of the particle phase increases the composite strength.

Impact Strength of the Composites

It is found that the toughness is indirectly proportional to increasing weight percentage of the SiC and TiC particles in the composite. Due to the addition of SiC and TiC in various percentages with Al, the material brittleness also has been increased. High brittleness led to decreased impact strength of the material.

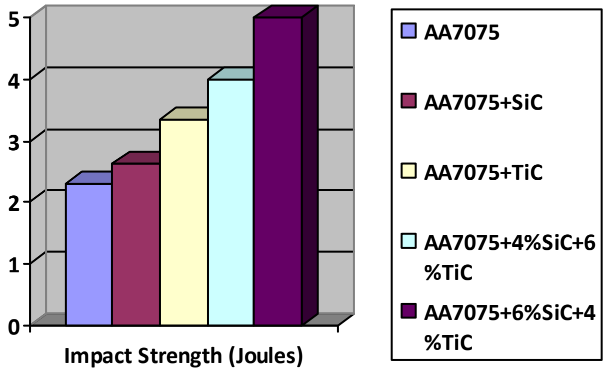

Figure 6: Graphical Representation of Impact Strength

Metallurgical Properties

The nature, type of reinforcement particles and their uniform distribution have a major role in influencing the characteristics of particulate HMMCs. The factors that rule the uniform spreading of particles are fluidity, solidification rate, type of reinforcement and the method of incorporation. Uniform distribution of particle phase helps in improving the mechanical behavior of HMMC. The first task is to uniformly distribute particles in the liquid melt and then to stop particles segregation during pouring and solidification. Wettability is one of the major constraints for uniform distribution of particles in the melt.

Figure 7: Microstructure of AL7075 +6% SiC +TiC 4%

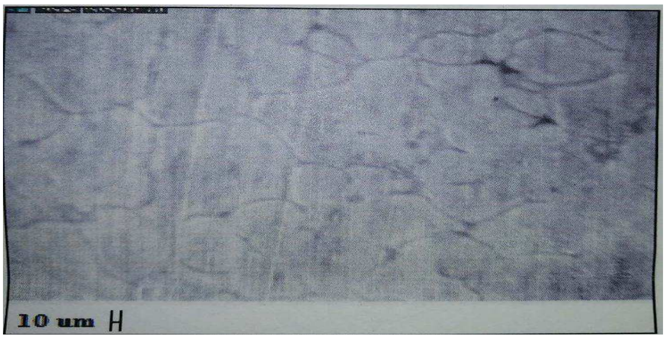

Figure 8: Microstructure of AL7075 90%+4% SiC +6% TiC

CONCLUSIONS

The following conclusions were obtained on the mechanical nature of stir cast hybrid MMCs (AL7075+SiC+TiC) from the experimental results.

- From the stir casting technique Al7075+SiC+TiC HMMCs were fabricated successfully.
- Hardness of cast Al7075 90%+6% TiC+4% SiC hybrid MMCs is increased by 40% in comparison with AL7075 matrix alloy.
- Hardness of cast Al7075 90%+4% TiC+6% SiC hybrid MMCs is increased by 30.4% in comparison with AL7075 matrix alloy.
- Tensile strength of Al7075 90%+6% TiC+4% SiC hybrid MMCs is increased by 13.4% in comparison with AL7075 matrix alloy.
- Tensile strength of Al7075 90%+6% TiC+4% SiC hybrid MMCs is increased by 7.4% in comparison with AL7075 matrix alloy.
- Tensile strength, compressive strength and yield strength increases with addition upto 5%TiC reinforcement and decreases at 5 wt% SiC.
- It was investigated that, composites containing 6% of weight Titanium carbide and 4% of weight Silicon Carbide reinforcements exhibits superior mechanical properties.

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